A. ABSTRACT

Multi-Model Ensemble Combination and Conditional Stochastic Weather Generation Tool for Improved Streamflow Forecast

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Total Project Cost: $292,948

Skillful basin wide streamflow forecasts at short (1-2 weeks) and long (seasonal and longer) time scales are important for efficient water resources management. This is particularly so in the Western US, which is semi-arid and its limited water resources are stressed due to unprecedented socio economic growth. The skillful ensemble hydrologic forecasts require (i) skillful hydrometeorological outlooks, (ii) suite of models – physical and statistical that captures the physical and climate features of the basin and provide ensemble forecasts conditioned on the outlooks and, (iii) an optimal combination tool. The outlooks have to be based on the short term weather forecasting information from NOAA/NWS and the seasonal climate forecast from NOAA. Current forecasts are provided by River Forecasting Centers based on a single physical model with limited ensemble generating capability and recent research suggests that a multi-model ensemble forecasting approach provides enhanced skills in the forecast than any single model. To this end this research proposes to develop two key tools - (i) a conditional stochastic weather generator to provide daily weather ensembles based on the NWS short term and NOAA seasonal outlooks and in-situ data including land surface observations to drive the RFC's physical model to provide ensemble streamflow forecast and, (ii) an optimal multi-model ensemble combination to provide a combined ensemble forecast from physical and statistical models. We will demonstrate the framework by applying it to the Upper Colorado River Basin. The forecasts in this basin are critical for efficient operation and management of major reservoirs and consequently, the impacts on water resources, agriculture, hydropower and aquatic environment in the South Western and Inter mountain region of Western US.

Approach Proposed

The work we propose will involve the following streams:

(1) Development of tools to "translate" short term and seasonal forecasts from NWS and NCEP, respectively, to basin scale ensemble hydrometeorological forecasts.
(2) Drive the physical model with the hydrometeorological ensembles to obtain ensemble streamflow forecasts.
(3) Develop a multi-site statistical ensemble streamflow forecast model
(4) Develop an optimal combination tool to combine these and other available forecasts to provide a multi-model ensemble forecast.
(5) Work with the water managers (USBR) in the basin to implement these forecasts for operations and management.

Dynamical Climate Predictability of the NCEP CFS in the Stratosphere and the Statistical Downscaling for Climate Prediction in the Troposphere

Principal Investigator: Ming Cai, Department of Meteorology, Florida State University
Co-Principal Investigator: Huug M. van den Dool, CPC/NCEP/NOAA
Performance period: May 1 2010 – April 30 2013
Total requested budget: FSU: $278K, CPC: $157K, Sum: $435K

Abstract

The primary objective of our proposed study is to explore a new source for the prediction skill of climate variability from intra-seasonal to interannual time scales, namely the stratosphere-troposphere coupling. We envision that in addition to well researched ocean-atmosphere interaction (ENSO) and land-surface interaction, this may be the new avenue of progress through modes of variability that involve the stratosphere, or more generally the hemispheric mass circulation from the tropical troposphere into the high latitude stratosphere, and back through the troposphere.

The three main proposed research activities are

Task A: To systematically evaluate the prediction skill for stratospheric anomalies in the 25-year (1982-2006) retrospective seasonal climate predictions made by NCEP's Climate Forecast System (CFS).

Task B: To explore the way of 'specifying' surface weather or its statistics (over a month) from (predicted values of) a few predictable modes in the stratosphere. In other words, we propose to identify some statistical diagnostic tools on the relationships between stratospheric circulation anomalies and the statistical distribution (or changes in the statistics) of tropospheric/surface synoptic scale weather events.

Task C: To explore how to utilize the information derived from the model-based stratosphere prediction and statistical-based stratosphere-troposphere coupling to improve the climate prediction skill of surface weather beyond the lead time of 2 weeks. We will develop a new set of products for winter season climate predictions at various lead times from a month to a season or longer.

The overall goal of the proposed research is to utilize the extra NWP skill in the stratosphere beyond inherent predictability time scale to be identified in "Task A" for climate predictions of tropospheric circulation anomalies by "downscaling" the stratospheric climate prediction (Task C) via the statistical diagnostic relations between the stratospheric and tropospheric anomalies to be identified in Task B. In essence, we propose a new hybrid climate prediction strategy: predicting the stratospheric circulation anomalies by a dynamically based general circulation model beyond the inherent predictability time scale and using the simultaneous diagnostic relation between the stratospheric and tropospheric circulation anomalies for climate predictions of the tropospheric climate variability. The proposed hybrid prediction strategy for troposphere/surface climate variability at seasonal and interannual time scales is akin to the strategy for weather forecasts in 1960/70s, which was to predict 500 hPa circulation using dynamical models and to forecasts surface conditions using (simultaneous) statistical downscaling from the 500 hPa to the surface (e.g., MOS).

Resolving the role of groundwater in multi-scale land-atmosphere dynamics using simulation, sensor networks and satellites: Juniata River Basin

Christopher J. Duffy, Kenneth J. Davis and Fuqing Zhang
The Pennsylvania State University

Prediction of flood and drought has proven particularly challenging in small upland river basins (1 to 10,000 km^2 and 1^{st} to 4^{th} order channel networks) which represent the major water generating areas to downstream, higher order rivers. Current prediction schemes for the most part, rely upon statistical methods, not physics-based prognostic models at these scales. Further, while advances in weather prediction have come from improved representation of soil moisture and vegetation fluxes, existing land surface schemes using in NWP models are limited to vertical moisture transport in the soil column and largely ignore deeper soil moisture processes and ground water. This proposal investigates the value of integrating a physics-based, highly data-constrained model of ground water hydrology for a river basin in central Pennsylvania into flood/drought prediction, and into NWP models.

We will address two primary hypotheses: 1) A bedrock-to surface layer hydrologic modeling system, driven by satellite observations of the land surface and meteorological reananalyses, will improve simulation of flood and drought conditions in the Juniata River basin at 1-10,000 km^2 spatial scales; and 2) Reanalysis of the ground water hydrology of the Juniata river basin using PIHM will significantly improve the accuracy of predictions of the basin-wide, daily surface energy balance at time scales where groundwater hydrology is predictable (days to months), relative to a prediction that does not include explicit modeling of ground water hydrology.

The project will bring together resources including the Penn State Integrated Hydrologic Model (PIHM), the National Science Foundation sponsored Critical Zone Observatory (CZO) at Shale Hills, PA, and the Penn State ensemble Kalman filter (EnKF) data assimilation system. PIHM will be implemented across the Juniata River basin, initialized with high quality, static land surface characteristics, driven by a combination of North American Regional Reanalysis (NARR) meteorological and Moderate Resolution Imaging Spectroradiometer (MODIS) vegetation inputs, and optimized using basin-wide stream flow and ground water table data for the period from 2000 through 2010. The optimized model and basin-wide hydrologic reanalyses will then be used to evaluate the skill of the model-data assimilation system in predicting flood/drought conditions in the basin as well as sensible and latent heat fluxes in the basin relative to current operational models. In the short-term, we anticipate that this reanalysis of basin hydrology could be used to improve flood and drought forecasting in this and other river basins. Longer-term goals of the research are to describe the influence of seasonal, inter-annual and decadal climate variability and change on extreme events (floods and droughts), and to progress towards a fully-coupled, multiscale hydrologic and atmospheric modeling system that could yield important benefits in long-term weather forecasting.

In terms of the FY2010 Climate Prediction Program for the Americas request for proposals, this proposal squarely addresses the request to "improve hydrologic predictions at regional scales at intraseasonal to interannual time scales," and to, "improve understanding and process modeling of land surface physics including soil moisture, vegetation, snowpack, groundwater and processes in complex terrain," two of the three elements called for in the request. This project has relevance to the first element of the call in that it has the potential to contribute to "climate predictability at intraseasonal to interannual time scales focusing on land memory effects." The research also addresses CPPA priority 3. "Climate-based hydrologic and water management applications at regional scales".

Collaborative Research: Analysis of IPCC-AR5 and CFS model simulated stratosphere-troposphere coupling and its link to Eurasian snow cover variability

Institutions: AER, Inc., CPC/NOAA
Investigators: Judah Cohen, Arun Kumar, Amy Butler
TOTAL BUDGET: $421,603.00
Budget Period: May 1, 2010 - April 30, 2013

The goals of the proposed research are to (a) analyze the output from IPCC AR5 class of models and the NCEP Climate Forecast System (CFS) hindcasts to assess the impact of stratosphere-troposphere (ST) coupling and Eurasian snow variability on the winter climate of North America, (b) further quantify atmospheric predictability associated with interannual snow variability using an operational prediction model, and (c) work with the operational community to improve climate forecasts from the intraseasonal to the interannual time scales by incorporating the predictive potential of snow variability into operational practices. The proposed work specifically addresses the goal of CPPA "to evaluate the ability of the IPCC-AR5 class models to simulate and predict ISI climate" and "improve understanding of climate predictability at ISI time scales focusing on stratosphere-troposphere coupling, land memory effects and weather-climate links."

Skillful climate predictions throughout the extratropics remain a challenge for both statistical and numerical models. For the winter season, ST coupling is now understood to play an important role in winter surface anomalies, especially for those that persist for longer than synoptic time-scales and therefore are important for determining seasonal means. Furthermore, a statistically significant link has been demonstrated between Eurasian snow cover extent and major ST coupling events. Snow cover anomalies often lead ST coupling events by two to three months, making snow cover a potential predictor of winter climate anomalies. Previous analysis has shown that the two regions where snow cover has the highest potential for skillful prediction are East Asia and the eastern United States; the latter will be the focus of this proposal.

Our proposed research will focus on diagnosing model output and performing additional experiments designed to study ST coupling and its link to snow cover variability. Our initial analysis will study archived atmospheric state variables from control (i.e., pre-industrial) and time-evolving GHG (i.e., climate of 20th Century and climate projection) GCM experiments from the IPCC AR4 and AR5 class of models. We will then compare the analysis from the IPCC AR4/AR5 models with a similar analysis using existing hindcast output from the CFS model. We will diagnose correlations between simulated snow cover variability and atmospheric temperatures, geopotential heights, winds and energy flux (Eliassen-Palm flux or the three dimensional wave activity flux) and compare with observed co-variability between snow cover and the atmosphere. This analysis will (a) assess the simulation of ST coupling in the IPCC AR5 class of models and in the CFS model compared against the observations, (b) quantify the influence of snow variability on ST coupling and climate variability over North America in the IPCC AR5 models and from the CFS hindcasts by comparing with the observations, and (c) provide an assessment of how much improvement in the simulation of the pathway by which snow anomalies influence climate variability over North America has been accomplished by comparing the analysis from the IPCC AR5 models and the CFS with a similar analysis performed from the IPCC AR4 class of models. Demonstrating improved simulations of ST coupling in the CFS model will enhance credibility of the CFS forecasts.

We will also carry out additional experiments in an effort to assess predictability of atmospheric anomalies associated with the interannual snow variability using an operational prediction model. Experiments will be designed to force the CFS with observed snow cover variability. Model output of atmospheric response to observed snow cover forcing will be analyzed and compared with observations and with archived CFS data where snow cover has not been prescribed. In a second set of GCM experiments we will identify and isolate large ST coupling events. Then we will re-run the model with initialized atmospheric conditions that preceded the stratosphere-troposphere coupling events but with varying amounts of snow cover. This set of experiments will help us determine whether the modeled ST coupling events were altered or modified by changes in snow cover extent.

A reasonable concern is that the CFS model cannot adequately simulate observed snow-atmosphere coupling and therefore snow experiments with the CFS will only yield negative results. However, for future model development it is critical to understand and document model errors and deficiencies in order to spur future model improvements, and we are only proposing enough model analysis and experiments to determine the CFS capabilities in regard to this important coupling. Whether realistic snow cover improves seasonal prediction or not, the results will be shared with the operational modeling community. Results from the analysis of archived model data and original GCM experiments will be submitted for publication.

An integrated view of the American Monsoon Systems:
observations, models and probabilistic forecasts

Dr. Leila M. V. Carvalho (PI) and Dr. Charles Jones (Co-PI)
Institute for Computational Earth System Science (ICESS)
University of California, Santa Barbara

May 1 2007 April 30 2010

Year 1: $113,229 Year 2: $122,915 Year 3:$141,937 Total: $ 378,081

Abstract

Climate Prediction Program for the Americas (CPPA) Science Plan indentified the need to "*explore a unified approach to understand the North American (NAMS) and South American (SAMS) monsoons systems, which constitute the two extremes of the annual cycle over the Americas and possible linkages between the two systems.*" This proposal will contribute to the CPPA implementation strategy by focusing on the interactions between the two systems and identification of common sources and limits of summer season predictability in the AMS. The main theme of this proposal is to develop a unified view of the AMS. Specifically, it addresses the FY2010 CPPA research priority of *Predictability and prediction of intraseasonal to interannual (ISI) climate variations and related impacts over the Americas*. The proposal will also evaluate the ability of global models from the World Climate Research Program (WCRP) Coupled Model Intercomparison Project (CMIP) to simulate the variability of the AMS in the present climate.

The project is comprised of four interconnected main goals. First, the project will investigate the extent to which the annual evolution of NAMS and SAMS and their temporal variability on ISI time scales can be represented with metrics that effectively describe changes in precipitation and atmospheric circulation in the Americas. Second, this will identify regional physical processes and teleconnections that control the interactions between NAMS and SAMS. Third, this project will evaluate the skill of WCRP CMIP coupled models in representing the observed variations in the AMS. Lastly, this project will implement diagnostic monitoring tools, identify sources of potential predictability and develop probabilistic forecasts of the AMS on subseasonal to seasonal scales. Specific objectives are:

I. Develop and validate indices for a unified approach to monitor and forecast the variability of the monsoon systems in the Americas.

II. Investigate the associations between the two monsoon systems, the importance of regional processes and remote atmosphere-ocean variations on ISI time scales in explaining these linkages.

III. Examine the degree to which simulations from the WCRP Coupled Model Intercomparison Project (CMIP-3 and CMIP-5) realistically represent the AMS and associations between the monsoons in the Americas.

IV. Use NCEP Climate Forecast System (CFS) model outputs (reforecasts and operational) to develop probabilistic forecasts of the American Monsoon Systems on subseasonal to seasonal lead times. Identify potential predictability sources of the AMS on ISI time scales.

Abstract

Title: Prediction of Intraseasonal Variability in the Americas
Investigators: Hoyos, Webster, Agudelo and Kim
Institution: Georgia Institute of Technology
Proposed Cost: $ 444,247
Budget Period: 03/01/10 - 02/28/13

Successful strategic and tactical decisions that support water resource management, agriculture, and hydroelectric power generation in the Americas, especially in monsoon areas, are only possible if precipitation forecasts on subseasonal to seasonal time scales are skillful. Subseasonal variability of precipitation is evident across the globe, including in North, South and Central America. During the boreal summer, large intraseasonal variability extends eastward across the Pacific Ocean over the equatorial and subtropical regions of North America. During the boreal winter, similar patterns of variance exist but with maximum variance in the southern hemisphere with maxima over Brazil and the South Atlantic Convergence Zone. Previous studies have suggested the existence of a link between North and South America intraseasonal variability with that in the Indo-West pacific basin. Despite its importance modulating climate and weather across the globe, numerical prediction models do not forecast skillfully and robustly intraseasonal variability. The skill of empirical predictions scheme is higher, but also have limitations predicting extreme events. In addition, empirical schemes are often deterministic and do not allow for a direct assessment of error growth associated with sensitivity to initial conditions. This proposal provides a hybrid methodology to improve the forecasting skill of extended rainfall predictions in the Americas by combining numerical weather predictions and empirical schemes into a single system capable of providing probabilistic forecasts using the different ensemble members available in numerical weather prediction models. To design an optimal operational hybrid scheme we will first assess the prediction and simulation skill of intraseasonal variability in the Americas from numerical weather prediction and climate models. We will also assess the interannual variability of intraseasonal variability in the Americas, and its potential impact on intraseasonal prediction. The proposed hybrid scheme uses the forecast circulation structure from each ensemble member and separates it into different temporal scales by projecting the numerical forecasts onto the most important multivariate spatio-temporal modes of variability and then uses the banded numerical forecasts as predictors in the hybrid empirical system.

Title: Atmosphere-Land Coupling and the Predictability of North American Drought

Institution: University of Miami, Rosenstiel School of Marine and Atmospheric Science

Investigators: Benjamin Kirtman (PI), Robert Burgman (Co-PI), Brian Mapes (Co-PI) and Chidong Zhang (Co-PI).

Budget Period: May 1, 2010 to April 30, 2013

Total Proposed Budget: $454,868

Abstract

The proposed research is based on the hypothesis that the predictability of persistent large-scale drought is due the competition among three processes:

(i) The nature of local coupled atmosphere-land feedbacks (i.e., strength, growth rate, saturation)

(ii) The predictability limiting affects of atmospheric noise or stochastic forcing

(iii) The remote forcing from low frequency global SST variability (e.g., AMO, PDO, NPO…).

We propose to test this hypothesis through a series of modeling experiments that isolate the relative importance of coupled atmosphere-land feedbacks vs. atmospheric stochastic forcing vs. remote SST forcing. These experiments include using the novel interactive ensemble coupling strategy (Kirtman and Shukla 2002) previously used to isolate coupled ocean-atmosphere feedbacks vs. atmospheric stochastic forcing, extended to the problem of atmosphere-land interactions. Part of our modeling strategy builds on the success of the US Clivar drought WG (http://www.usclivar.org/Organization/drought-wg.html) and the international Global Land-Atmosphere Coupling Experiment (GLACE) by explicitly leveraging their experimental protocol. We have chosen to focus on the question of North American drought because of its societal importance to US interests; however, the approach is equally applicable to terrestrial hydro-climate predictability on multiple space and time scales throughout the globe.

B. Abstract

Changes in Intraseasonal to Interannual Variability of the Pan American Monsoons Under a Warmer Climate and Their Impacts on Extreme Events Assessed by the CMIP5 Models and Observations

Institutions: The University of Texas at Austin, NCEP/NWS/NOAA, University of Colorado, Boulder

Principal investigator: Rong Fu, Co-Investigators: Kingtse Mo Weiqin Han

Three-Year Total Budget $ 348,723/3 yrs ($255,723 for U Texas, $93,000 for CPC)

Funding Period: May 1, 2010 - April 30, 2013

We propose to characterize the changes of intraseasonal, seasonal and interannual variability (ISI) and their impact on extreme events over the Pan America monsoon region as simulated and projected by the Coupled Model Inter-comparison Phase Five (CMIP5) and National Oceanic and Atmospheric Administration (NOAA) Climate Forecast System (CFS) models. Our analysis will first focus on observations of changes in rainfall and temperature characteristics and extreme weather events in the recent past and their underlying mechanisms. The observational results will be used to assess the skills of the CMIP5 class models in reproducing the observed ISI variability and their changes, in focusing on the mechanisms that control ISI variability in the Pan American monsoon regions and their links to sea surface temperature (SST) changes over the adjacent oceans, the local land surface process and the extratropical synoptic weather systems, as well as bias estimations. The results of this model evaluation will be used to filter-out "unrealistic" models from the climate projections and also for model bias corrections.

The proposal aims to address the following questions:

a) Will the spatial patterns, ISI variabilities and statistical distributions of temperature and rainfall shift significantly in a warming climate in the Pan American monsoon region? How would such changes impact the intensity and frequency of the droughts, floods and heat waves?

b) What external forcings are responsible for these changes and how would local land surface feedbacks contribute to these changes? What processes are key in determining the influence of these forcings? How are changes in the North American and the South American monsoon connected?

c) How realistically can global climate models simulate the key process that control changes of ISI in the Pan American monsoon region? How can such model evaluation be used to reduce random error and biases in climate projections?

We will extensively use observations and reanalysis products including in situ observations from surface and upper air meteorological networks, remote sensing datasets, the North American Regional Reanalysis (NARR), the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis (CDAS), the North-American Land Data Assimilation System (NLDAS) and the CFS reanalysis (CFSR) when it becomes available. We will also analyze daily and monthly outputs from ensemble simulations of the CMIP5 class models for the pre-industrial scenario, the 20th century simulations forced by estimated increase of the anthropogenic forcing, and the 21st century under

The American Midsummer Drought: Causal Mechanisms and Seasonal–to–Interannual Predictability | *Columbia University and University of Maryland–College Park* **|** Karnauskas, Giannini, Seager, and Busalacchi **|** $444,566 **|** 6/1/2009–5/31/2012

Abstract:

The Intra–Americas Sea (IAS) region– including the northeastern tropical Pacific Ocean, Caribbean Sea, Gulf of Mexico, western tropical Atlantic Ocean, and all adjacent landforms– represents a fascinating natural climate laboratory due to a confluence of diverse oceanic, orographic, atmospheric, and remote influences. The IAS region is also home to a large portion of humanity whose livelihood depends critically upon the spatiotemporal variability of precipitation. Throughout most of the IAS region, the rainy season spans roughly May through October with a break in precipitation in July–August known as the midsummer drought (MSD). This feature of the rainfall climatology is highly unique to the IAS region, and is particularly evident over Central America and the adjacent northeastern tropical Pacific Ocean. Indeed, the MSD is such a pervasive phenomenon that crop insurance programs incorporate what little information is known of the MSD in pricing and triggering policies in Central America. Since the recognition of the MSD as a regular climatological feature in the early 1960s, much effort has been directed toward characterizing and understanding the MSD. Both local processes (e.g., SST–convection–radiation feedback) and aspects of the general circulation (e.g., the North Atlantic subtropical high) have been shown to influence the MSD. To date, however, a unifying explanation for the very existence of the MSD has yet to emerge. As a result, our understanding of the interannual variability and– most importantly– predictability of the MSD is only in a nascent stage. Seasonal–to–interannual climate predictions for the IAS region would benefit greatly from an understanding of the causal mechanisms for the existence and variability of the MSD. We propose to first focus on analysis of observations: satellite and *in situ* measurements, as well as state–of–the–art global and regional reanalyses to diagnose the dominant mechanisms of the MSD in the IAS region. Secondly, we will use state–of–the–art general circulation models to test specific hypotheses regarding the dominant mechanisms of the MSD and its variability. This approach will allow us to thoroughly examine and identify the features of the global atmospheric circulation and, especially, the role of the ocean, that are crucial for predicting seasonal hydroclimate variability in the IAS region.

Research Proposal to the NOAA Climate Program Office, FY2010

Climatic Predictability of Extreme Floods in the United States

<u>*Project Participants*</u>:

Columbia University/LDEO/IRI: Upmanu Lall, Yochanan Kushnir, Andrew Robertson, Jennifer Nakamura

<u>*Total Proposed Cost*</u>: **$434,707** <u>*Budget Period*</u>: *May 2010 – April 2013*

ABSTRACT

Of all climate-related disasters, floods account for the largest average annual losses. Only a limited climatic perspective on floods in the United States exists. This includes the identification of the seasonality and typical mechanisms (e.g., frontal or connective precipitation) important for floods by subregion. Climate change analyses have led to either no clear assessment of changes in flood potential, or to projections of dramatically increased frequency of extreme floods. The anticipated intensification of the atmospheric hydrological cycle and the increased atmospheric moisture holding capacity under warming, render increasing flood risk plausible. However, it is unclear whether the climatic processes associated with extreme floods are well modeled in global and regional climate models, and whether such models provide predictability for assessing the frequency and intensity of rainfall responsible for extreme floods in the United States with spatial specificity relevant for hydrological analysis of floods.

Our work shows that extreme floods (annual exceedance probability less than ~ 0.1) in most river basins in the United States are associated with a distinct atmospheric moisture transport pattern, where the moisture source is typically in the oceans rather than associated with local convection. Over much of the Western United States, we have been able to demonstrate statistical predictability of the annual maximum flood conditional on pre-season Pacific SSTs. For a region in Brazil we are able to demonstrate that the annual maximum flood at each of the stations can be modeled using concurrent large scale, seasonal climate predictors, and a spatial scaling model for the flood process indexed to the drainage area of the site. Consequently, our hypothesis is that river basins aggregate the spatio-temporal climate signal in terms of synoptic and seasonal atmospheric moisture transport in a way that allows empirical connections to be drawn between slowly varying climate fields and the severity, incidence and location of extreme floods over N. America. If these connections can be quantitatively assessed, modeled and understood, then a basis for assessing changes in flood risk using GCMs or empirical methods could be developed for seasonal prediction and for climate change projections.

The research proposed here seeks to develop an exploratory statistical-dynamical approach for "downscaling" flood risk from climate models through an analysis of the causal structure of the entire ocean-atmosphere-land chain of the flood process. This entails (a) use of historical, re-analysis and GCM data for the diagnostic analyses of the causal structure from the spatio-temporal hydroclimatic data associated with the extreme floods in each of the regions of the United States; (b) Bayesian model development for assessing the conditional probability distributions across the causal chain, leading to a conditional flood risk estimate given either GCM state variables or observed/re-analysis data fields, and (c) assessments of projections of flood risk at selected locations for the upcoming season or for a climate change scenario.

Influence of Convective Systems on Intraseasonal to Interannual Variability of the Intra-American Monsoon
Program Element CPPA
Funding Opportunity # OAR-CPO-2009-2001430
Competition # (for CPPA) 2117994
CFDA # 11.431

Proposed Cost: $312,370
Budget Period: 1 June 2009 – 31 May 2012

Principal Investigator: Brant Liebmann
CIRES Climate Diagnostics Center

Co-Principal Investigator: George N. Kiladis
NOAA/ESRL/Physical Sciences Division

Co-Principal Investigator: Carolina S. Vera
University of Buenos Aires

Abstract

We propose to examine the contribution from large-scale organized transient disturbances to intraseasonal and seasonal total rainfall of the intra-Americas Sea region (IAS). The focus will be on disturbances with periods of less than 30 days affecting the tropical regions from Mexico to northern South America. Kelvin waves, cold surges and easterly waves are of primary interest. A visual inspection of Hovmoeller diagrams reveals many examples of Kelvin disturbances that form near the dateline and propagate eastward. When they encounter South America, convection - as depicted by outgoing longwave radiation (OLR) - typically increases over tropical regions. These disturbances propagate into the Atlantic, where they substantially affect the intertropical convergence zone there (Wang and Fu 2007). Kelvin waves can also form in-situ over the Amazon basin during southern summer when cold surges originating in the middle latitudes of South America force convection at the Equator (Liebmann et al. 2008). During southern winter, when cold surges are stronger and Amazon convection is weak, they frequently propagate across the Equator and into the Caribbean. Mesoscale convective activity is seen to be significantly modulated by equatorial waves, and this will also be examined in some detail. Our initial analyses indicate that convective activity is enhanced when westward propagating disturbances encounter Kelvin waves and cold surges. It is likely that problems in representation of the climate of the IAS by models suffer from an incorrect representation of subseasonal disturbances. In addition to analyzing the aforementioned disturbances in observations, a similar analysis will be made for the coupled general circulation models that will constitute the basis of the Intergovernmental Panel on Climate Change 5th Assessment Report.

The questions we propose to address are the following:

1) What is the seasonal cycle and interannual variability of Kelvin wave activity, and how is Kelvin wave activity related to large-scale, slowly varying phenomena?
2) How do Kelvin and other equatorial waves modulate mesoscale variability and the diurnal cycle?
3) Although transients are prominent in satellite-based observations of cloud top such as OLR, to what extent do they account for seasonal totals in the IAS?
4) Do westward propagating disturbances amplify or diminish when they encounter Kelvin waves or cold surges from either hemisphere?
5) Where are the transients that affect the IAS initiated?
6) Do coupled atmosphere-ocean models represent well the subseasonal transients, and to what extent do errors in their climatology result from problems in representing these disturbances?
7) Can rainfall be predicted with skill for several days in advance from trajectories of disturbances as they approach the IAS?

Drizzle and Cloudiness Transitions in Southeast Pacific Marine Stratocumulus

D. B. Mechem, University of Kansas

Budget: $312,206
Budget Period: 07/01/2010 to 06/30/2013

The representation of boundary layer clouds in global climate models (GCMs) has been identified as a leading cause driving uncertainties in future climate change scenarios. Low cloud properties are highly variable in space and time, with the climatically important shortwave cloud forcing differing widely between cloudy and clear regions. Most visibly notable in marine boundary layer systems are pockets of open cells (POCs), regions of low cloud fraction, high precipitation rate, and low aerosol concentration, most commonly embedded in extensive regions of solid stratocumulus. The causal mechanisms explaining the evolution from solid cloud to POC, however, are not well understood. Specifically of interest are the transition regions between solid and broken cloud, since these are thought to be the focal point for driving mesoscale variability.

The Variability of the American Monsoon Systems [VAMOS] Ocean-Cloud-Atmosphere-Land Study — Regional Experiment (VOCALS-Rex) field campaign took place over the southeast Pacific (SEP) region during Oct-Nov 2008. The proposed research takes advantage of the fact that the C-band radar on board the NOAA R/V Ronald H. Brown was the sole observational platform in VOCALS able to sample the near-instantaneous three-dimensional mesoscale structure of the precipitation field, while also capturing evolution of individual cells over their entire lifecycles. The VOCALS radar observations included an unexpected discovery: the frequent occurrence of regions of very high reflectivity (>40 dBZ), unprecedented for boundary layer clouds. The VOCALS data, along with preliminary simulations, suggests the following overarching question: *Fundamentally, what drives cloud system variability in marine boundary layer clouds?*

The proposed research seeks to evaluate, in a numerical modeling framework, various hypotheses related to boundary layer drizzle processes and cloud variability over the SEP. These hypotheses are formulated to address the following questions directly related to SEP cloud systems: i. What are the leading factors in establishing drizzle and mesoscale cloud variability?; ii. What are the predominant mechanisms active at the transition between solid stratocumulus and POCs?; iii. What are the dynamic and microphysical processes associated with cloud field evolution from unbroken stratocumulus to POC and back to solid cloud? The study proposes a "near-LES" simulation framework, combined with unique ship-based observational datasets that provide a robust and comprehensive observational constraint on the model.

This proposal directly addresses the CPPA goal to "improve understanding and process modeling of cloud, planetary boundary layer, and microphysics...," with the VOCALS field campaign being specifically mentioned in the original call. Furthermore, this proposal would leverage undergoing CPPA-funded work, particularly the ship-based observational efforts.

North America Hydroclimate Variability in CMIP5 Model Climate Simulations and Projections: Are Simulations Improving and Projections Converging?

PIs: Alfredo Ruiz-Barradas & Sumant Nigam
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PROJECT SUMMARY

Analysis of simulations and projections of regional hydroclimate variability over North America, especially the Central United States (U.S)., from the CMIP3 models indicate that the region imposes a notable challenge for global climate models. Difficulties arise due to the imperfect representation of processes that generate precipitation variability over the Central U.S. and the lack of consistent projections of tendencies and extremes in summer from the models analyzed.

We propose a two tier analysis for the climate simulations and projections from the models participating in the new CMIP5 effort: An extensive evaluation and intercomparison of *tendencies* and *extremes* in projections from pentad to seasonal scales, and analysis of the mechanisms that generate summertime precipitation variability over the Central U.S.. Convergence of *tendencies* and *extremes* among the models will give some certainties to our societies, while a good assessment of the *mechanisms* in the models will give reassurance in the projections. The projections to be analyzed will be those emanated from the new scenario given by the Representative Concentration Pathway 8.5 which is characterized by increasing greenhouse gas emissions in the 21st century.

The analysis of *mechanisms* that generate precipitation variability over the Central U.S. in summer will be based of the analysis of the structure of the components of the atmospheric water balance in model simulations and projections. The main mechanism will be revealed by the relative magnitude of the regressions of regional precipitation indices on precipitation, moisture fluxes, and evapotranspiration; this analysis will be complemented with a correlation analysis of July precipitation with the previous months' precipitation, to assess, indirectly, the strength of soil moisture feedback. Because observations indicate that precipitation variability is generated by remote forcing, two different versions of empirical function analysis (EOF) will be employed to detect the main modes of variability in the simulated and projected climates: 1) a rotated EOF analysis of summer SSTs and 700hPa heights, and an Extended EOF analysis of SSTs. Comparisons with observations, especially in near-term projections will reveal the realism of the mechanisms generating regional hydroclimate variability in the models.

The analysis of *tendencies* will include the whole region, however, the analysis of *extremes* and *droughts* will be focused on the Central U.S.,with secondary attention on Southwestern U.S.. Credibility in the projected *tendencies* will be given by their proximity with those observed at the end of the 20th century. The assessment of *extremes* will be done at pentad, monthly and seasonal resolutions, but the assessment of *droughts* will be done at low-frequency scales of seasonal data via histogram analysis.

Evaluation of the Tropical Storm Track Across the Intra-Americas Sea in IPCC AR5 Models and the Mechanisms of Change in a Warmer Climate

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04/2010-03/2011: $127,253 04/2011-03/2012: $128,759 04/2012-03/2013: $132,662
Total Request for 04/2010-03/2013: $388,674

Abstract

The Intra-Americas Sea (IAS) includes the Gulf of Mexico, Caribbean Sea and tropical northeast Pacific Ocean, the latter of which is the most prolific hurricane formation region in the world per square meter. Heavy rains arrive over the IAS during boreal summer, when the Inter-Tropical Convergence Zone (ITCZ), or axis of the tropical storm track, migrates north off the equator and SSTs warm throughout the region. Localized moisture convergence over land areas within the IAS is important for hydropower, agriculture and fresh water supplies. IAS moisture transport into northern Mexico and Southwest U.S. is also important for agriculture and populations in these regions.

Several studies point out the critical role that orography plays in present day mid-latitude and tropical storm tracks. Recent work also suggests that the Caribbean low-level jet (CLLJ) influences storm track activity within the IAS. Studies of tropical storm tracks within the projected warmer conditions of the 21st century find reduced storm track activity in the tropical Atlantic and a shift of the tropical northeast Pacific storm track southward. The intensity of tropical storms overall appears to remain unchanged in studies that have accounted for a mean shift in the tropical mean sea surface pressure due to warmer temperatures. However, predicting storm intensity changes remains a difficult task, as this parameter is more dependent on model resolution than storm frequency.

The following questions are raised by these studies: i) Will the roles of orography and the CLLJ change if the storm track in the tropical eastern Pacific shifts southward in the 21st century? ii) How would such a change affect intensity of storms in the tropical eastern Pacific? iii) How would changes in the position of the tropical eastern Pacific storm track affect the precipitation over land areas of the IAS and NAM regions?

This study proposes to investigate these questions through the following set of analyses:

- Obtain 20th century tropical storm track statistics using state-of-the-art reanalyses.
- Assess tropical storm track statistics of all AR5 model 20th century scenario data available at greater than daily resolution against the reanalyses' statistics.
- Use high-resolution regional model simulations to assess physical mechanisms associated with several real cases of developing and non-developing tropical depressions within the IAS using the reanalyses as boundary forcing for these simulations.
- Force the regional model for actual cases of 21st century storms/waves from AR5 models that produce realistic track statistics for the 20th century and compare mechanisms of storm initiation and intensification with the cases from step 3.

This project will make use of a numerical technique in which actual features of the tropical storm track (easterly waves and mature storms) in the AR5 models will be simulated using a high-resolution regional model, rather than using idealized simulations of a mature tropical storm forced with the general conditions of a warmer climate. This approach permits changes in genesis mechanisms to be evaluated.

Understanding atmosphere-ocean coupled processes in the southeast Pacific

Principal Investigators:

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Total proposed cost: $365,389

Budget period: March 2010 – February 2013

Abstract

Coupled atmosphere-ocean general circulation models (CGCMs) have systematic errors in the southeast Pacific (SEP) region. The biases need to be traced back to specific model characteristics, such as certain aspect of the physical parameterizations, in order to provide useful guidance on how to improve the model simulation. The primary goal of this proposed study is to improve our understanding of the structure and mechanisms of CGCMs' systematic biases in the southeast Pacific. To realize this goal, we need to examine, step by step, the key biases in its AGCM, the key biases in its OGCM, and the key biases in its ocean-atmosphere feedback processes when the AGCM and OGCM are coupled together. Therefore, we propose to:

(1) Diagnose the structure and mechanisms of the AGCM biases in stratocumulus/stratus clouds, marine boundary layer (MBL), and surface fluxes in the SEP region in IPCC AR5 CGCMs;

(2) Analyze the upper ocean currents, thermal structures and heat budget in the SEP region in IPCC AR5 CGCMs;

(3) Examine the ocean-atmosphere coupling processes in the SEP region in IPCC AR5 CGCMs, especially how well the ocean-atmosphere feedbacks are simulated; and

(4) Conduct forced OGCM experiments to examine the sensitivity of upper ocean processes to atmospheric forcings relevant to AGCMs' biases.

A framework for improving land-surface hydrologic process representation in CLM over California

CPPA Opportunity # OAR-CPO-2010-2001720)

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Total Proposed Cost: $540,000

Budget Period: May 1, 2010 to April 30, 2013

PROPOSAL SUMMARY

To address the Climate Prediction Project for the Americas (CPPA), formerly known as the Global Energy and Water Cycle Experiment (GEWEX) American Prediction Project (GAPP) research priority: "***Climate-based hydrologic and water management applications at regional scales***," this proposal has selected California as a data-rich, high population, and scientifically productive study region. California's wdater supply systems are straining to keep up with economic growth and urban development. The groundwater resource—which accounts for 30-40% of the water California uses -- is diminishing at a rate of millions of acre-feet per year. The state has experienced two major droughts and three major floods since 1980's, and California continues to grow and build. Combined, these regional changes pose an urgent need for accurate models and reliable predictions of key hydrologic processes of regional climate change and guidance for California's water management responses.

The UC Irvine Center for Hydrometeorology and Remote Sensing (CHRS) proposes to respond specifically to the call for "Efforts of development and improvement of integrated (i.e., coupled snow, surface water, soil moisture and groundwater) hydrologic models…data assimilations, model evaluations against high-resolution datasets, and parameterization of water management (e.g. irrigation, reservoir storage, and release, groundwater withdrawal etc.) for use in basin- to continental-scale models." To address this challenge, proposed integrated hydrological models would include: 1) a remote sensing satellite-based snow model, 2) a modified Community Land Model (CLM) Land Surface Model (LSM), and 3) a two-dimensional MODFLOW (The USGS Modular ground-Water Model—the Ground-Water Flow Process). In addition to simulating the basic hydrologic processes, these coupled models will aim specifically to improve estimations of interactive mechanisms: snow cover and Snow Water Equivalent (SWE) estimation using in-situ and satellite data; the partition of snow water into runoff, soil moisture and groundwater recharge; parameterization of seasonal irrigation and groundwater pumping over the state, and groundwater discharge/recharge to/from river flows. .

Among only a few U.S. states that have accumulated decades of ground-based water records, California maintains extensive networks for regular hydrological measurements. Taking advantage of California's wealth of historical and current data, we propose to use long-term data for model parameter calibration and sequential data assimilation techniques to substantially improve model performance. Calibrating model parameters using information from long-term observations will optimize values for key model parameters, reducing model uncertainty. The sequential data assimilation technique—the Sequential Bayesian Filter with Monte Carlo implementation (SBF-MC) will integrate near real-time hydrological measurements from satellites (e.g. top layer soil moisture) and/or ground sites (e.g. stream gauge data and groundwater well monitoring) to both improve the predictions of model state variables and quantify prediction uncertainty.

The Role of Land Surface Physics in Controlling Intraseasonal Precipitation Variability over Complex Terrain

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David J. Gochis, National Center for Atmospheric Research (NCAR)
Budget Period: May 1, 2010 to April 30, 2013; Total Project Budget: $444,568

1. ABSTRACT

The prediction of hydrometeorological processes is hindered by the limited capabilities of integrated models that properly handle land surface physics in complex terrain. A key issue for improved intraseasonal simulations in western North America is capturing the variability in land surface conditions in mountain areas. Two of these areas – central Rocky Mountains in U.S. and Sierra Madre Occidental in Mexico – provide ideal areas for developing hydrometeorological model improvements as they span a clear hydroclimate gradient from cold to warm-season dominated regimes. Two related questions need to be addressed to enhance warm-season hydrometeorological forecasts in mountain regions: *How do land surface conditions and their memory enhance or surpress convective precipitation in mountain regions*? and *How do variations in climate and vegetation along the continental hydroclimate gradient impact the relations between land surface physical processes and convective precipitation*? Both questions are fundamental to understanding intraseasonal climate processes and improving operational models and their reanalysis products in the region.

Our proposal focuses on improved process simulations using hydrometeorological models in two mountain regions as proxies for similar systems across the North American hydroclimate gradient. We are especially interested in demonstrating how regional topographic features interact with the land surface state and its memory (soil moisture and temperature, vegetation and irrigation/reservoirs) to modify intraseasonal precipitation characteristics that control hydrologic response (flooding and drought). The study focuses on regions with low intraseasonal predictability in convective precipitation, soil moisture and streamflow, thus requiring new physical insight obtained from field data, remote sensing and numerical modeling. We will take advantage of intense observation and forecasting periods carried out by the proponents and an existing network of research and operational instruments. Our efforts are aimed towards improved characterization of intraseasonal variability in precipitation, land surface conditions and streamflow through use of two versions of a coupled hydrometeorological modeling system.

To address the science questions outlined above, we propose the following project elements: (1) Hydrometeorological data collection and diagnostic analysis in the two mountain areas to define the characteristic behavior of the regional hydrometeorology and land surface conditions and construct an observational/reanalysis archive for model testing; (2) Conduct idealized hydrometeorological modeling experiments that mimic local topographic conditions and explore the impact of prescribed (and perturbed) land surface state variations in space and time on convective precipitation and its characteristics; and (3) Three-dimensional hindcast and forecast experiments using a coupled hydrometeorological model that incorporates key findings of the idealized model runs to demonstrate how different land surface physics in each region yield important up-scaled impacts on precipitation and streamflow variability at intraseasonal time scales. Comparison of the two mountainous regions along the hydroclimate gradient will allow a direct test of the relevance of land surface memory on intraseasonal precipitation variability.